10/553408
1 JC06 Rec'd PCT/PTO 17 OCT 2005

AIRCRAFT FLIGHT SAFETY DEVICE AND METHOD WHICH ARE INTENDED FOR AN AIRCRAFT FLYING IN INSTRUMENT METEOROLOGICAL CONDITIONS AND WHICH ARE USED INDEPENDENTLY OF INSTRUMENT FLIGHT INFRASTRUCTURE

The present invention relates to a method and apparatus for making aircraft flight safe under instrument flying conditions away from instrument flight infrastructures.

Throughout the entire airspace of the planet, regulations distinguish between two types of flying conditions due to meteorological conditions:

· visual meteorological conditions (VMC); and

· instrument meteorological conditions (IMC).

With VMC conditions, aircraft are allowed to fly without assistance from takeoff to landing. They must comply with visual flight rules (VFR) that are defined internationally.

Under IMC conditions, aircraft are authorized to fly only if they satisfy three conditions:

· they are fitted with the special equipment for instrument flying;

· they fly only in defined zones where aviation infrastructure and air navigation services provide control, separation, and guidance of aircraft; and

· they satisfy instrument flight rules (IFR) likewise defined internationally.

Flying in IMC conditions (i.e. instrument flying conditions), as considered by the present invention, thus imposes severe restrictions on what airspace is authorized. In particular, zones at low altitude (apart from airport zones) or zones between areas in relief are not accessible since they generally lie outside IFR infrastructures, i.e. outside the range of radio navigation means and outside the coverage of air navigation radars.

Such restrictions make it impossible to accomplish certain missions at low altitude, for example rescue

missions or tactical military missions under IMC conditions, and also make it impossible to land on grounds not fitted with IFR infrastructure and air control (i.e. outside IFR infrastructures).

US patent No. 6 421 603 (Pratt et al.) describes a method of evaluating the risks of interference between an intended flight plan and obstacles, in which the flight plan is defined in the form of a coarse trajectory made up of a sequence of segments having parameters defining their extent in three dimensions (horizontally and vertically); a route generator converts those segments and parameters into parallelipipeds or polygons in order to constitute a route model; stationary obstacles are represented in the form of terrain rectangles given altitudes and subdivisions, while moving obstacles are modeled by means of segments, in a manner similar to the flight plan. Interference is detected by comparing the respective models for the itinerary and the obstacles; an alarm is triggered when interference is detected.

That system does not enable the pilot to be shown the portion of the route that corresponds to the detected interference.

US patent No. 6 424 889 (Bonhoure et al.) describes a method of generating a horizontal trajectory for avoiding zones that are dangerous for an aircraft; that method comprises determining circles that are tangential to the trajectory at an initial point and at a final point; determining tangents to the circles and to models of the dangerous zones; selecting pairs of tangents that define a skeleton trajectory; and determining a coarse trajectory comprising circles interconnecting the tangents.

US patent No. 5 555 175 and French patent No. 2 712 251 (D'Orso) describe a method of providing assistance in piloting an aircraft in which obstacles are detected ahead of the aircraft; those obstacles having summits that are closest to a vertical avoidance

trajectory are selected; and as a function of the selected obstacles, a piloting curve is calculated that is presented to the pilot to provide assistance in avoiding the detected obstacles.

An object of the invention is to propose a system for providing assistance in flying an aircraft on instruments outside the range of IFR infrastructures.

An object of the invention is to propose a system of providing assistance in flying a rotary wing aircraft at low altitude.

An object of the invention is to propose an interactive method of determining a piloting setpoint making it easier for the pilot on board an aircraft to avoid obstacles, together with apparatus for implementing the method.

An object of the invention is to propose a system of providing assistance in piloting an aircraft that is improved and/or that remedies at least a portion of the drawbacks of previously known methods and devices.

The present invention provides a method of making aircraft flight safe, in particular for a rotary wing aircraft, under instrument flying conditions (IMC) and away from instrument flight rules (IFR) infrastructures, so as to give the aircraft the ability to perform missions in all weathers and in any location.

To this end, said method of the invention is remarkable in that it comprises the steps of:

a) determining a safe route for the aircraft;

b) causing said aircraft to follow the safe route as determined in this way; and

c) while following the safe route, automatically performing the following operations using means that are not connected to air navigation infrastructures, and in particular using exclusively means on board the aircraft:

$\alpha$) verifying the safety of the actual trajectory of the aircraft;

β) verifying the safety of the aircraft flight relative to any other aircraft; and

γ) providing assistance in perceiving the environment outside the aircraft.

In the meaning of the present application, the term route means a succession of waypoints in three-dimensional (3D) space, that are required for a mission, together with segments or "legs" interconnecting these waypoints in pairs.

Thus, the method in accordance with the invention makes it possible to provide all of the functions needed for executing a flight under IMC conditions, using only means that are available on board the aircraft, and that are not connected to IFR infrastructures. As described below, the reliability and the complementarity of the means used for this purpose enable all of these functions to be performed with a level of safety that is at least as good as for a flight executed with support from an IFR infrastructure.

In addition, since the flight is executed independently of any IFR infrastructure, it escapes from restrictions of airspace specific to IFR coverage. This makes it possible to access all airspace, thus making it possible to perform rescue missions in particular, regardless of weather conditions and regardless of location.

Naturally, the availability of an aircraft in all weathers and in any location, and in particular the availability of a rotary wing aircraft such as a helicopter, as obtained by the present invention is advantageous in very many fields of activity: emergency rescue, ambulance between hospitals, police, civil protection, regular transport of passengers, ... .

Advantageously, in above-mentioned step a), in order to determine a safe route for the aircraft, the following steps are performed:

a1) an operator constructs a route for the aircraft using an interactive graphics route-construction tool coupled to an interference calculator and to a memory;

a2) determining any interference between the route and a model of the terrain overflown by the aircraft; and

a3) presenting any interference to the operator to enable construction of the route to be modified so as to cause said interference to disappear;

the sequence of said steps a1) to a3) being repeated until all of said interference, if any, has disappeared.

Thus, while creating or modifying a segment using the method of the invention, it is possible to show which zones of segments are in conflict with the terrain; route construction is based on a "man-machine" loop that enables the desired result to be reached in a few successive steps; the invention also makes it possible to adapt a mission that is already being executed.

Furthermore, and advantageously, while the flight is being executed, during cα), in order to verify the safety of the actual trajectory of the aircraft, the following steps are performed:

α1) verifying that the deviation between a theoretical route for the aircraft and the actual position of the aircraft remains less than a predetermined value;

α2) verifying that the immediate future trajectory of the aircraft is safe relative to theoretical terrain; and

α3) verifying that the immediate future trajectory of the aircraft is safe relative to real terrain.

Furthermore, and advantageously, in step cγ), at least while the aircraft is close to the ground, the following steps are performed:

· picking up images of the outside environment and superposing them on the real outside view; and/or

· generating a safety line situated above the relief, and superposing it on said real outside view.

Furthermore, and advantageously, in step cγ), at least some of the following information is presented to at least one pilot of the aircraft:

· the hypsometric environment;

· the aviation environment; and

· any aircraft situated at a distance from said aircraft that is less than a predetermined distance.

The present invention also provides apparatus for making flight safe for an aircraft, in particular for a rotary wing aircraft, under instrument flying conditions and away from instrument flight infrastructures.

According to the invention, said apparatus is remarkable in that it comprises at least:

· an interference calculator capable in particular of calculating interference between a route and a theoretical terrain;

· means for acquiring parameters relating to the aircraft and to the outside environment, in particular relating to the position of the aircraft in three-dimensional space;

· a memory for storing a route that has been constructed;

· a memory containing a model of the terrain to be overflown;

· display means, e.g. a screen, a head-up display or the equivalent, together with the necessary interface;

· an interactive graphics route-construction tool;

· a navigation calculator; and

· a piloting system.

The apparatus of the invention makes it possible to perform all of the functions needed for executing a flight under IMC conditions, without requiring the usual IFR infrastructure in order to do so. In addition, the reliability and the complementarity of the various means of said apparatus enable all of these functions to be performed at a level of safety that is at least as good

as that during a flight executed with support from IFR infrastructures.

Consequently, the apparatus of the invention provides the ability to fly in all weathers and at any location.

In a particular embodiment, said apparatus further includes at least one means for providing assistance in perceiving the environment outside the aircraft.

The sole figure of the accompanying drawing shows clearly how the invention can be implemented. This figure is a block diagram of apparatus in accordance with the invention.

The apparatus 1 in accordance with the invention shown in the figure is for making safe the flight of an aircraft (not shown), in particular a rotary wing aircraft such as a helicopter, under instrument flying conditions (IMC) and away from instrument flying infrastructures (IFR infrastructures).

To this end, said apparatus 1 is used to implement a method in accordance with the invention that consists in the following steps:

a) determining a safe route for the aircraft;

b) causing said aircraft to follow the safe route as determined in this way; and

c) while following the safe route, automatically performing the following operations while making use solely of means on board the aircraft and as specified below:

α) verifying the safety of the actual trajectory of the aircraft;

β) verifying the safety of the aircraft flight relative to any other aircraft; and

γ) providing assistance in perceiving the environment outside the aircraft.

To do this, said apparatus 1 comprises:

· an interference calculator 2 suitable, in particular, for calculating interference between the route and terrain;

· means 3 for acquiring parameters as specified below relating to the aircraft and to the outside environment, said means 3 possibly being constituted in particular by sensors, air speed and pressure units, inertial navigation units, or a satellite positioning system;

· a memory 4 for storing a constructed route;

· a memory 5 containing a model of the terrain that is to be overflown;

· display means 6, in particular a display screen;

· an interactive graphics route-construction tool 7;

· a navigation calculator 8; and

· a piloting system 9 of conventional type, not described further herein and comprising in the usual way at least one piloting screen or the equivalent, and possibly also an autopilot. Said piloting system 9 is connected by a link 10 to the navigation calculator 8.

In a preferred embodiment, said navigation calculator 8 includes a usual navigation function 11, and said calculator 2 together with said memory 4 are integrated in said navigation calculator 8.

The first above-mentioned step a) in performing all-weather flying lies in preparing and making safe the route relative to the terrain and possible obstacles.

In this situation, two sets of circumstances can arise:

· either the entire route all the way to the intended landing point is defined on the ground before the flight. Under such circumstances, the route is prepared using a tool 7 that need not necessarily be on board the aircraft; and

· or else only the first segments of the route are defined, in order to save on preparation time (emergency missions) or because the exact destination is not known

when starting. Under such circumstances, the interactive route-construction tool 7 must necessarily be on board the aircraft.

The interactive tool 7 includes ordinary pointer means (e.g. a mouse, a keypad, a touch-sensitive screen) that can be actuated by an operator, in particular a pilot of the aircraft, that is coupled to the calculator 2, and for which the result of actuation is displayed on a screen, in particular on the display screen 6.

According to the invention, the route constructed by the pilot using the route-construction tool 7 is input into the calculator 2 which then superposes this theoretical route on the digital terrain model taken from the memory 5 in order to determine possible interference between them, while making allowances for safety margins (minimum distances that are acceptable relative to relief, both in a vertical plane and in the horizontal plane). Such interference is displayed on the display screen 6 so that the pilot can modify the route until all interference has disappeared.

By following this process, the pilot can progressively construct a desirable safe route and cause it to be stored in the memory 4 of the calculator 2.

Safe flying requires the safe route as determined in this way to be followed accurately.

Accurate guidance of the aircraft along the route is provided in conventional manner (and not described in greater detail) by the navigation calculator 8 of usual type.

In addition, the display screen 6 serves to display the positions respectively of the aircraft and of the intended route.

The navigation calculator 8 (navigation function 11) guides the aircraft very precisely over the safe route. However, the trajectory actually followed by the aircraft differs slightly from the theoretical route. Thus, in order to provide the best possible level of safety, it is

necessary in above-mentioned step c$\alpha$) to verify that the trajectory actually followed by the aircraft is safe.

To do this, the following steps are performed:

$\alpha$1) the calculator 2 verifies that the distance between the theoretical route of the aircraft and the actual position of the aircraft remains acceptable;

$\alpha$2) verifying that the immediate future trajectory of the aircraft is safe relative to the theoretical terrain; and

$\alpha$3) verifying that the immediate future trajectory of the aircraft is safe relative to real terrain.

In a particular embodiment, in order to implement above-mentioned step $\alpha$1), the navigation calculator (navigation function 11) uses information coming from the acquisition means 3 and the theoretical route to calculate the deviation, if any, between the aircraft and the theoretical route. If this deviation from the theoretical route becomes greater than predefined safety margins, the pilot is warned by alarms, e.g. displayed on a piloting screen of the piloting system 9.

Making safe relative to the theoretical terrain (step $\alpha$2) is performed by a conventional ground collision avoidance system (GCAS).

The GCAS forms part of a set 12 of systems S1, S2, ..., Sn provided on board the aircraft. Said set 12 forms part of the apparatus 1 in accordance with the invention.

In addition, making safe relative to the real terrain and to obstacles (step $\alpha$3), is performed by a conventional obstacle warning system (OWS) making use of sensors that detect obstacles and relief in darkness or under bad weather conditions. The OWS is integrated in the set 12 and includes a display screen or the equivalent for providing the pilot with a safe line over the obstacles, e.g. as defined in French patent No. 2 712 251, together with a warning device for indicating the presence of a dangerous obstacle.

It should be observed that the above-mentioned GCAS and OWS calculate a trajectory that is extrapolated in the short term and they compare that with the theoretical terrain (for the GCAS) or with the real terrain (for the OWS). The trajectory is extrapolated solely from immediate variations of the speed vector, without seeking to rejoin the programmed route, unlike the above-mentioned process (step α1) that is implemented by the calculator 2.

Furthermore, step cβ) of the method of the invention can be implemented by an aircraft collision avoidance system (ACAS) that detects the presence and the position of any other aircraft in a radius compatible with the reaction capacities of the aircraft and the pilot, and provides the pilot with information about potential conflicts and with piloting setpoints for avoiding collision.

Furthermore, assistance in perceiving the outside environment (step cγ) is implemented by systems described below forming part of said set 12.

This assistance is essential in all stages of flight close to the ground, not only during landing and/or takeoff, but also when flying at very low altitude. During other stages of flight, it increases the safety level of the flight by giving the pilot additional information that can enable the pilot to optimize piloting actions and reactions.

The following two families of systems are needed for stages of flight close to the ground.

Under poor visibility conditions, vision close to the ground is improved by the use of sensors such as cameras of the forward looking infrared (FLIR3) type, of the low light level (LLL) type, of the radio detection and ranging (RADAR) type, of the light detection and ranging (LIDAR) type, or any other equivalent means, producing images that are superposed on the real outside view.

Another appearance for potentially dangerous relief is calculated by the OWS which provides the pilot with a safe line over the obstacles.

Advantageously, during other stages of flight, knowledge of the environment around the aircraft can be reinforced by various complementary systems, serving to perform the following:

· presenting the hypsometric environment on a conventional navigation screen of the aircraft in the form of terrain sections and horizontal views showing up dangerous relief around the aircraft;

· showing the aviation environment of the aircraft on the same vertical and horizontal sections, i.e. physical infrastructure (beacons, airports, ...) and virtual infrastructure (air traffic zones, reporting points, ...); and

· showing aircraft detected by the ACAS in the aerial environment being overflown, which system marks them as a function of their respective danger levels.

Consequently, the above-described set of means constituting the apparatus 1 in accordance with the invention serves to perform all of the functions needed for executing a flight under IMC conditions. The reliability and the complementarity of the means used make it possible to perform all of these functions with a level of safety that is at least as good as for a flight executed with support from an IFR infrastructure. In addition, since the flight is executed independently of any IFR infrastructure, it escapes from airspace restrictions specific to IFR coverage. It thus becomes possible to access all airspace, which makes all kinds of mission possible, regardless of meteorological conditions and geographical location.